International Journal of Applied Mathematics, Sciences, and Technology for National Defense
Volume 1, Issue 3, 97-106.
e_ISSN: 2985-9352, p_ISSN: 2986-0776
https://www.journal.foundae.com/index.php/JAS-ND
DOI : https://doi.org/10.58524/app.sci.def.v1i3.234

Mathematical modeling of basal body temperature influence on menstrual cycle, length of sleep, and stress levels as detection of fertile period (ovulation) in women

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Article Info

Article history:

Received: June 19, 2023
Revised: November 03, 2023
Accepted: November 15, 2023

Keywords:

Basal Body Temperature
Menstrual Cycle Fertile
Period Detection
Ovulation

Abstract

Basal body temperature is the temperature when the body reaches the resting phase or does not perform any activity. Basal body temperature is influenced by factors such as the quality of a person's length of sleep, stress, and menstrual cycle patterns. The benefit of checking and monitoring basal body temperature for a woman is to determine when a woman starts to enter the ovulation period, making it easier for couples who want a target pregnancy. The measurement method was carried out in the morning right after waking up using a thermometer flanked in the armpit area by applying three repetitions of measurements within a period of two months with the number of sample participants of 10 cadet students of military biology study program with an age range of 19-21 years. This type of research is carried out observationally and analytically using longitudinal data. The analysis used in this study was by conducting a statistical mathematical model trial by analyzing the p-value. The results showed that in the paired test there was a significant influence of the relationship of basal body temperature on the menstrual cycle at the time before menstruation and when menstruation. The researcher's suggestion is to conduct further research with larger participants of samples and the presence of sample variations in observations because not all biologists do significant research with the statistical method.

To cite this article: Rahayu, T., Hasudungan, A., Afiya, R., Farradila, V. M., & Rachmawati, R. N. (2023). Mathematical modeling of basal body temperature influence on menstrual cycle, length of sleep, and stress levels as detection of fertile period (ovulation) in women. *International Journal of Applied Mathematics, Sciences, and Technology for National Defense. 1*(3), 97-106

INTRODUCTION

Body temperature is the result of a balance between heat production and heat loss in living things. The average core body temperature of 37o C marked heat transfer in blood vessels to maintain the uniformity of the core body temperature regardless of changes in ambient temperature. Blood flow is controlled according to the body's metabolic needs and the need to maintain core temperature. Basal body temperature can be said to be the temperature condition achieved by the body when resting, sleeping, or not doing any activity (Barron & Fehring, 2005). The optimum standard for detecting ovulation is through ultrasound; however, there is another simple, inexpensive, and easy-to-use method of self-detection, namely the assessment of basal temperature

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(Zinaman, 2006; Germano & Jennings, 2006; Pyper and Knight, 2001). This examination is strongly influenced by hormonal changes. An increase in basal temperature of 0.2°C occurs since an increase in progesterone levels due to the formation of the corpus luteum in ovulation. The menstrual cycle in women can be estimated by observing basal body temperature values during one cycle (Kim et. all, 2016). Basal body temperature is a temperature condition achieved by the body when resting, sleeping, or not doing any activity (Risqiwati & Nurimalita, 2017). Basal body temperature measurement is influenced by the time to check body temperature, consistency in data collection time, stress, sleep patterns, and body health. In general, the basal temperature pattern of the body tends to be lower during the menstrual phase and the follicular phase then increases by 0.3-0.5 degrees Celsius to the luteal phase (Risqiwati & Nurimalita, 2017). Research conducted by Simic, it was found that in the menstrual phase and the beginning of the follicular phase, the basal temperature of the body is low. Then along with the increase in sex hormones in the preovulation and ovulation phases, there is an increase in the basal temperature of the body. The menstrual cycle is a process cycle that involves changes in hormones and reproductive organs characterized by the decay of the endometrial wall which results in changes in basal body temperature in women. So, the difference in basal temperature can be used as an indicator of phase change in one menstruation cycle. This menstrual cycle begins on the first day of menstruation, followed by a pre-ovulatory period called the follicular phase. After the ovulation phase, it will go into a post-ovulation phase called the luteal phase until the last day before the next menstruation. One previous study showed that passively measurable outputs by direct mechanistic bonding with female reproductive physiology, such as sustained body temperature, could be used for pregnancy testing. The increase in body temperature (BBT) during pregnancy, and its putative relationship to progesterone, has been recognized for about a century (Simic &Ravlic, 2013; Risqiwati & Nurimalita, 2017; Grant & Smarr, 2022). Several studies by developing applications related to the menstrual cycle and basal body temperature include Moh Syukri who developed a monitoring application based on mapping the basal temperature graph of the female body in the morning as a monitoring tool for ovulation in one menstrual cycle based on hormonal changes that affect it as a fertility monitoring medium (Yazed and Mahmud, 2017). Previous research was carried out estimation of menstrual cycles using the Covarian Stationary Time Series Analysis method with Basal Body Temperature, with this method an analysis of the body temperature cycle was carried out to predict the next menstrual cycle (Kim et.all, 2016). Body temperature will increase shortly after ovulation caused by an increase in the hormone progesterone because the nature of the hormone is thermogenic or produces heat. According to Taylor (1976), progestins cause an increase in basal body temperature by 1.0 -1.5° F which begins immediately after the time of ovulation and persists during the luteal phase of the menstrual cycle [Marks et. all]. However, it turns out that a person's body temperature is influenced by several factors, including basal metabolism speed, sympathetic nerve stimulation, growth hormone, thyroid hormone, reproductive hormone, and environment. Temperature changes are associated with the menstrual cycle, basal body temperature and peripheral temperature are affected due to changes in reproductive hormones, research to find out whether digital temperature measurements with Wrist Skin Temperature (WST) can detect temperature changes in the menstrual cycle of 48 women participating in the observational study found that the average initial temperature of the luteal phase increased by 0.33 °C. In addition to the menstrual cycle stress exposure factors generate an endocrinal, autonomic, and behavior response that allows an organism to adapt to a changing environment. These parameters prove that human body temperature is a response to stress (Vinkers et al., 2013). Homeostatic and circadian mechanisms affect skin vasodilation, peripheral vasoconstriction, and basal metabolism, all of which alter the rate of loss and gain of body heat (Krauchi and Wirz, 1994). The positive relationship between rhythms in performance and body temperature has been verified by studies that have controlled factors that can affect body temperature and performance, such as light exposure, activity, posture, nutrition, and drug intake (i.e., constant routines) (Wright, Hull, & Czeisler, 2002).

METHOD

The research design adopted an observational and analytical approach, utilizing longitudinal data to explore the relationships between basal body temperature, menstrual cycle patterns, sleep duration, and stress levels. This comprehensive methodology allowed for a detailed investigation into the dynamic interactions among these variables over time. The inclusion of 18 participants with consistent habits and environmental conditions enhanced the internal validity of the study, ensuring that the observed effects were more likely attributed to the variables under investigation rather than external confounding factors. The longitudinal nature of the study provided a unique opportunity to capture the temporal dynamics of basal body temperature variations and their correlation with the menstrual cycle, sleep duration, and stress levels. The measurement method involved taking BBT readings in the morning immediately after waking up. A thermometer was placed in the armpit area, and three repetitions were performed to ensure the accuracy and reliability of the data. This meticulous approach aimed to capture the most representative basal body temperature readings, minimizing the impact of external factors on the measurements. The integration of multiple variables in the analysis sought to provide a more nuanced and accurate understanding of the factors influencing fertility, offering valuable insights for both research and practical applications in women's reproductive health. By employing mathematical modeling techniques, this study aimed to develop a predictive model for identifying the fertile period in women based on the flowchart as shown in Figure 1.

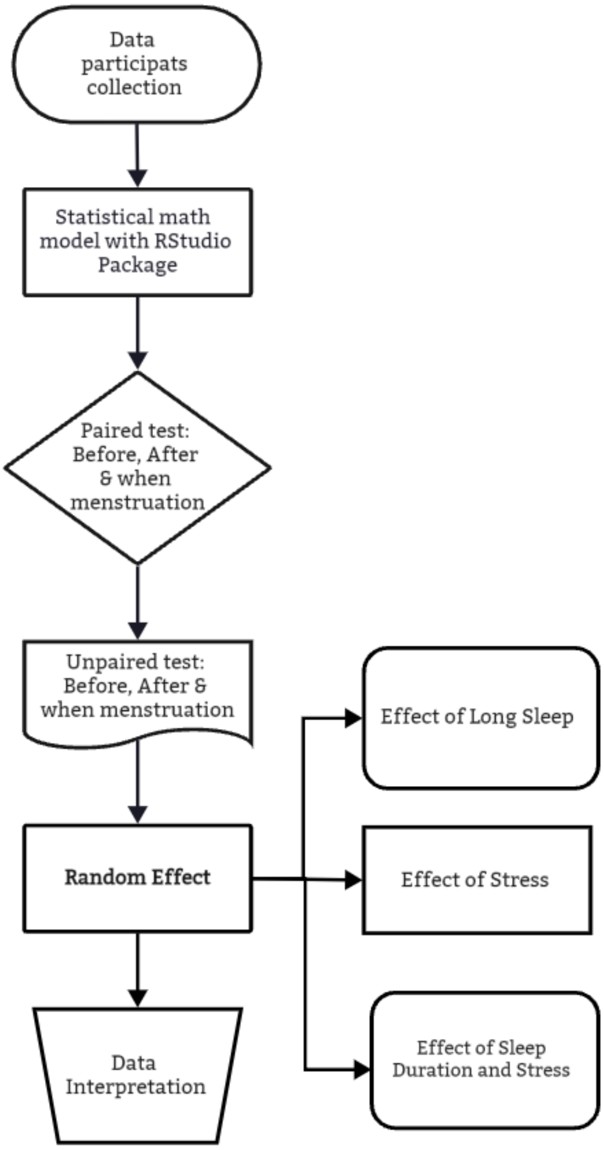

Figure 1. Flowchart of mathematical modeling research to obtain statistically significant models in biological cases

RESULTS AND DISCUSSION

Observational data

Table 1 is the result of observations that have been carried out during the study.

Table 1. Menstrual data

ID	Y	LT	TIME	STR
1	35.42	Under	BM	No Stress
1	34.98	Under	M	Stress
1	35	Under	AM	No Stress
2	35.15	Under	BM	No Stress
2	34.9	Upper	M	Stress
2	35.2	Upper	AM	No Stress
3	35.5	Under	BM	Stress
3	35.26	Upper	M	Stress
3	34.58	Under	AM	No Stress
4	35.4	Under	BM	Stress
4	35.37	Upper	M	Stress
4	35.35	Under	AM	No Stress
5	35.49	Under	BM	Stress
5	35.63	Under	M	Stress
5	34.6	Under	AM	Stress
6	35.56	Under	BM	Stress
6	35.6	Under	M	Stress
6	35.54	Under	AM	Stress
7	35.5	Under	BM	No Stress
7	35.4	Under	M	Stress
7	35.78	Under	AM	No Stress
8	35.24	Under	BM	No Stress
8	34.74	Under	M	Stress
8	34.91	Under	AM	No Stress
9	34.95	Under	BM	No Stress
9	34.95	Upper	M	No Stress
9	45.08	Under	AM	No Stress
10	35.1	Under	BM	Stress
10	35.05	Under	M	Stress
10	35.38	Under	AM	Stress
ID	Y	LT	TIME	STR

Data analysis

Paired Test

i) Before Menstruation with when

Menstruation Difference	:	+0.143
Result	:	temperature decreases from before menstruation and during menstruation
t-value	:	2,162
p-value	:	0.059
α	:	0,1
H0	:	There is no significant influence between before menstruation and during menstruation
H1	:	There is a significant influence between before menstruation and during menstruation
Result	:	p-value $> \alpha$ (H1 accepted)
Output	:	There is an influence of significance between before menstruation and when menstruation

ii) When Menstruation with After

Menstruation Difference	:	-0.954
Result	:	temperature increase from menstruation and after menstruation
t-value	:	-0.927
p-value	:	0.378
α	:	0,1
H0	:	There is no significant influence between menstruation and after menstruation
H1	:	There is a significant influence between menstruation and after menstruation
Result	:	p-value $> \alpha$ (H0 accepted)
Output	:	There is no significant influence between menstruation and after menstruation

iii) Before Menstruation and After

Menstruation Difference	:	-0.8110
Result	:	temperature decreases from before menstruation and after menstruation
t-value	:	-0.777
p-value	:	0.457
α	:	0,1
H0	:	There is no significant influence between before menstruation and after menstruation
H1	:	There is a significant influence between before menstruation and after menstruation
Result	:	p-value $> \alpha$ (H0 accepted)
Output	:	There is no significant influence between before menstruation and after menstruation

Unpaired Test

i) Before Menstruation with

Menstruation Difference	:	$+0.143$
Result	:	temperature decreases from before menstruation and during menstruation
t-value	:	1,219
p-value	:	0.238
α	:	0,1
H0	:	There is no significant influence between before menstruation and during menstruation
H1	:	There is significant influence between before menstruation and during menstruation
Result	:	p-value $> \alpha$ (H0 accepted)
Output	:	There is no significant influence between before menstruation and during menstruation

ii) When Menstruation with After

Menstruation Difference	:	-0.954
Result	:	temperature increase from menstruation and after menstruation
t-value	:	-0.949
p-value	:	0.355
α	:	0,1
H0	:	There is no significant influence between menstruation and after menstruation
H1	:	There is a significant influence between menstruation and after menstruation
Result	:	p-value $> \alpha$ (H0 accepted)
Output	:	There is no significant influence between menstruation and after menstruation

iii) Before Menstruation and After

Menstruation Difference	:	-0.811
Result	:	temperature decreases from before menstruation and after menstruation
t-value	:	-0.809
p-value	:	0.429
α	:	0,1
H0	:	There is no significant influence between before menstruation and after menstruation
H1	:	There is a significant influence between before menstruation and after menstruation
Result	:	p-value $> \alpha$ (H0 accepted)
Output	:	There is no significant influence between before menstruation and after menstruation

Random effect

i) Effect of long sleep on basal body temperature

	Value	Std. Error	DF	t-value	p-value
Intercept	35,2797	0.0888	8	397,1225	0,000
LT1	-0.1086	0.2048	7	-0.5302	0,612

	Num DF	Den DF	F-value	p-value
(Intercept)	1	8	191075.06	$< .0001$
LT	1	7	0.28	0.6123

	Variance	Std Dev
(Intercept)	0.005292539	0.07274984
Residual	0.098647753	0.31408240

H0	:	There is no significant effect between the length of sleep on body temperature during menstruation
H1	:	There is a significant influence between the length of sleep on body temperature when menstruating
Result	:	p-value $> \alpha$ (H0 accepted)
Output	:	There is no significant influence between before menstruation and after menstruation

ii) Effect of stress on basal body temperature

	Value	Std. Error	DF	t-value	p-value
Intercept	35,2835	0.5329	14	66,2046	< 0.0000
LT1	0.8037	0.8034	14	1,0003	0,3341

	Num DF	Den DF	F-value	p-value
(Intercept)	1	14	7984,573	$< .0001$
LT	1	14	1,001	0.3341

	Variance	Std Dev
(Intercept)	2.83E-02	0.0002
Residual	3.98E+06	19.941.036.895

H0	:	There is no significant effect between the length of sleep on body temperature when menstruating
H1	:	There is a significant influence between the length of sleep on body temperature when menstruating
Result	:	p-value $> \alpha$ (H0 accepted)
Output	:	There is no significant effect between the length of sleep on body temperature when menstruating

iii) Effect of sleep duration and stress on basal body temperature

	Value	Std. Error	DF	t-value	p-value
Intercept	35,2797	0.0888	27	34,6874	0,000
LT1	-0.1086	0.2048	27	-0.5237	0,6047

	Num DF	Den DF	F-value	p-value
(Intercept)	1	27	1365,6615	$< .0001$
LT	1	27	0.3057	0.5849

H0	:	No significant effect between the length of sleep and stress on body temperature
H1	:	There is a significant effect between length of sleep and stress on body temperature
Result	:	p-value $> \alpha$ (H0 accepted)
Output	:	No significant effect between the length of sleep and stress on body temperature

iv) Effect of sleep duration on basal body temperature during menstruation

	Value	Std. Error	DF	t-value	p-value
Intercept	35,2333	0.1307	8	269,5455	0,000
LT1	-0.1133	0.2066	8	-0.5483	0,5984

	Num DF	Den DF	F-value	p-value
(Intercept)	1	8	120.779,9	$< .0001$
LT	1	8	0.3	0.5984

H0	:	There is no significant effect between the length of sleep on body temperature during menstruation
H1	:	There is a significant influence between the length of sleep on body temperature when menstruating
Result	:	p-value $> \alpha$ (H0 accepted)

Output	:	There is no significant effect between the length of sleep on body temperature during menstruation

v) Effect of stress on basal body temperature during menstruation

	Value	Std. Error	DF	t-value	p-value
Intercept	35,2144	0.1046	8	336,6029	0,000
LT1	−0.2644	0.3308	8	−0.7993	0,4471

	Num DF	Den DF	F-value	p-value
(Intercept)	1	8	12.5701,57	< .0001
LT	1	8	0.64	0.4472

H0	:	There is no significant effect of stress on body temperature during menstruation
H1	:	There is a significant influence between stress on body temperature during menstruation
Result	:	p-value $> \alpha$ (H0 accepted)
Output	:	There is no significant effect of stress on body temperature during menstruation

vi) Effect of sleep duration and stress on basal body temperature during menstruation

	Value	Std. Error	DF	t-value	p-value
Intercept	35,2333	0.3130	7	112,5429	0,000
LT1	−0,0567	0,2362	7	−0,2398	0,817
STR1	−0.2267	0.3858	7	−0.5874	0,5753

	Num DF	Den DF	F-value	p-value
(Intercept)	1	7	1.3671,693	< .0001
LT	1	7	0,276	0,6155
STR	1	7	0.345	0.5753

H0	:	There is no significant effect of stress on body temperature during menstruation
H1	:	There is a significant influence between stress on body temperature during menstruation
Result	:	p-value $> \alpha$ (H0 accepted)
Output	:	There is no significant effect of stress on body temperature during menstruation

Data Interpretation

In the pairing test, the p-value of 0.059 was obtained before menstruation and during menstruation, the p-value of 0.378 was obtained during menstruation, and after menstruation, the p-value of 0.457 was obtained before menstruation and after menstruation. In the unpaired test, the p-value of 0.238 was obtained before menstruation, and during menstruation, the p-value of 0.355 was obtained during menstruation and after menstruation, the p-value of 0.429 was obtained before menstruation and after menstruation. Meanwhile, when added to the random effect, the effect of sleep duration and stress effects shows a less significant effect on results. Sleep patterns are explained by the complex interaction between genetic, behavioral, environmental, and social factors. Based on the recommendation of sleep duration (Chaput et al., 2018) that for ages in the range of 18-25 years, the amount of sleep is 7-9 hours. In the sample used in that year range a length of sleep less than 7-9 hours was categorized under while a length of sleep of more than 7-9 hours was categorized as upper.

From the results of the p-value model analysis, there was a significant relationship between menstruation both before, moderate, and after menstruation, but there was a significant influence between basal body temperature on length of sleep and stress. When compared in theory, the basal temperature of the body is influenced by a person's menstruation cycle because when there is a collapse of the endometrial wall in the menstrual cycle, it implies a decrease in basal body temperature compared to before menstruation increases by 0.3-0.5 degrees Celsius to the luteal phase so that in general the pattern Basal body temperature tends to be lower during the menstrual phase and follicular phase. The increase, if analyzed statistically, does have a very small effect but there is still an influence of menstrual cycle patterns on the basal temperature of a person's body. Not all biological phenomena can be analyzed by statistical modeling. There are internal and external factors in the body of living things, especially humans, on the results of observations carried out, for example in terms of lifestyle, habitat, food, stress levels, hormones, and others. So that the parameters used in this observation need to be expanded and more specifications such as age, consistency of data retrieval time, and other things.

CONCLUSION

The result significant influence of the relationship of basal body temperature on menstrual cycles, patterns of length of sleep and stress levels have been carried out. The model analysis carried out the p-value value was significant at the time of menstruation and during menstruation which means that there is a significant influence of the relationship of basal body temperature between before menstruation and when menstruation with paired test analysis.

Based on paper (Fay DS, 2013) that insignificant data in statistics are not necessarily insignificant in biological cases. Based on this finding, further studies are needed with a large number of participants with various variations.

AUTHOR CONTRIBUTIONS

Each author of this article played an important role in the process of method conceptualization, simulation, and article writing

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